Computerized Detection of Macular Edema Using OCT Images Based on Fractal Texture Analysis

Athira S. C.
L.B.S Institute of Technology for women, Poojappura, Trivandrum, India
athirasc5@gmail.com

Reena M. Roy
L.B.S Institute of Technology for women, Poojappura, Trivandrum, India
reenamroy@gmail.com

Aneesh R. P.
Regional Centre IHRD Medical College, Trivandrum, India
aneeshprakkulam@gmail.com

***Abstract*— Macular edema (ME) is a significant cause that results in blindness among majority. It happens due to the anomalous leakage and builds up of fluids within macular region. Anything that relates with the performance of eyes can drive the chances to become a ME patient. ME can occur as a downstream of eye related surgeries, degradation due to aging or any eye disorders causing inflammation. The main fact about ME that if the disease is not identified and diagnosed at the earlier stages, the chance of recovery is minimal and can ultimately affect the ability to see. One of the main causes of ME is the disease which can injure blood vessels in the retina. Laser photocoagulation and vitrectomy are the common method available now for diagnosing the disease. Optical Coherence Tomography alias OCT, an advanced imaging technique to capture retinal layer region. Different algorithms were implemented to detect ME from OCT images, but early detection of ME is not possible. This paper utilizes segmentation based fractal texture analysis (SFTA) to derive the feature vector. Graph based segmentation employs in the detection of layers and QDA classifies the ME images. This algorithm will help the ophthalmologist to treat the patient at early stages. The algorithm is deployed successfully on a macular edema dataset, with 97.5% accuracy rate.**

***Keywords*— Macular Edema, Graph shortest path, OCT, layer detection, SFTA, thickness profile, QDA**

I. INTRODUCTION

Eye, one of the most vital organs in the human body which act as a magician who allows human to see the beauty of world. The eyes provide the sense of vision and controls entire movement or working of our body in coordination with brain. Human eye is made up of three layers. Each layer is formed by various anatomical structures. Fibrous tunic, the outermost layers consists of cornea and sclera, followed by vascular tunic or uvea. It provides the space for choroid, ciliary body, pigmented epithelium and iris. Retina is the third and innermost layer [1], [2]. The macula is sensible part for central vision. This is located at the centre of the retina. Macula regulates the visual capabilities, by defining the image perceived by human eye in the center of field of vision. This vision is needed for carrying the basic activities like driving, reading, writing etc. This pigmented area is in an oval shape and posses a radius of 2.75 mm [3], [6]. Fovea is a tiny dip loaded with light sensitive cells and located at the center of Macula [4]. Figure 1& 2 encompasses the basic anatomy of human eye and the Macular region respectively.

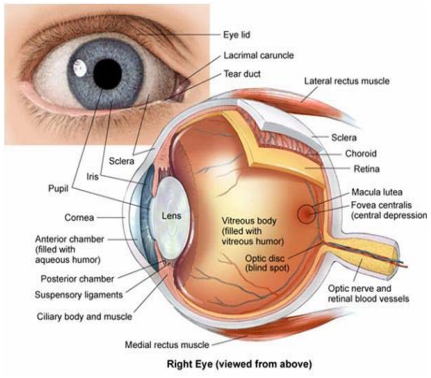

Fig. 1: Anatomy of Human eye

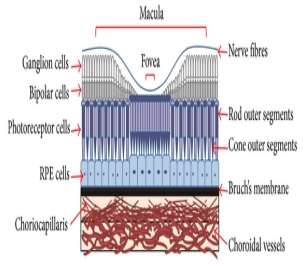

Fig 2: Macula region

Diseases degrade the macular portion of retina, thereby blurring the human central vision [4]. There exist distinct types of macular diseases. The common types are Macular Edema, Macular Hole, Age Related Degradations, Central Serous Retinopathy, Pigment Epithelium, Choroidal Neovascularization and the Forster-Fuchs etc. [4], [5].

Ophthalmologists diagnose ME by examining human eye for any anomalies within the retinal region. Different clinical tests can be performed to determine the extent of degradation and the exact location of the disease [9].

A. Visual acuity test

A common eye examination technique to determine vision loss and to diagnose ME is the visual acuity test. It utilizes a standard chart or card with letters printed in rows. The letters are printed in such a way that the size decreases gradually while moving towards the bottom. The patient is made to cover one eye and has to read the smallest line of letters can be perceived. Similar process has to be carried out covering the second eye as well.

B. Dilated eye exam

This method is used to examine any degradation within the retina. It checks for any leakages or cysts in the blood vessels and helps to determine the health of the macula. In this method, eye drops are placed in the eyes to widen the pupils. This provides a greater and detailed view of the retinal region.

C. Fluorescein angiogram

Fluorescein angiogram is a commonly used eye examination techniques, this method encompasses a special dye being injected into the eyes. A camera is used to take pictures of retina, while the dye moves through blood vessels. The eye specialists then examine these pictures to check for any anomalies within the macula.

D. Optical coherence tomography

OCT gives layer wise information of the retina. It utilizes specially designed light and camera device to examine cellular layers within the retina. This technique is employed to determine the thickness of the retina and thereby diagnosing any anomalies or swell within macula. Ophthalmologists use the OCT scan results to track the recovery from disease [2], [6].

There are different techniques used to detect the macular disorders. A few of those are dilated eye exam, Fluorescein angiogram, Optical coherence tomography, Vitrectomy, Ophthalmoscopy, Fundus photography and Fundus fluorescein angiography. The main disadvantages with these methods are that the detection of ME is not possible at the early stages. OCT is the modern eye examination technique used in the detection of eye related diseases. But there is no well-defined algorithm that can to automatically detect ME in the budding stages. The Ophthalmologists used to perform a visual or direct study of the OCT scans thereby the chances of missing the crucial points are very high and hence tend to human born errors. Additionally the past technique utilizes the Exudates. Morphological restoration methodology is utilized to determine the contours of these exudates. The algorithm were limited to be tested on a small images only, hence cannot be applied on all types of retinal images. The algorithm was limited to be tested on a small images only, hence cannot be applied on all types of retinal images. Figure 3 portraits the visual capabilities of a healthy eye versus ME diseased eye.

Fig 3 (a) Healthy eye. (b) ME pretentious vision [21].

II. PROPOSED SYSTEM

Modern medical technology is the only scope to fight against the ever increasing eye related diseases. ME is one of the major diseases that degrades vision. This paper basically emphasizes on developing a computerized method to identify ME at its earlier stages. It utilizes graph based segmentation, SFTA, and QDA algorithms for identification and categorization of ME. The block representation of the proposed system is depicted below.

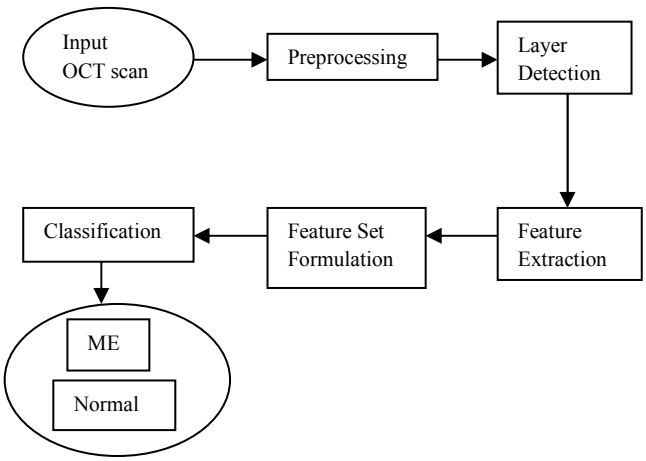

Fig 4: Block Diagram for Proposed System.

A. Preprocessing

The preprocessing of image is carried out to enhance the quality of image to be tested. This will increase the accuracy, and precision with the images are being tested against ME. The primary step is to resize the image to a significant level. This is followed by enhancing the image with multiple techniques. OCT images are grayscale images so that grey level conversion is not needed. Most of the OCT dataset contains scanned records. Median filter is applied to reduce noise [7].

B. Layer Detection

To accurately detect the choroid and ILM layers from the denoised OCT scan [7]. Graph based algorithm is used here to detect layer from the OCT images. The layers can be considered as a graph G with vertices V and edges E [17]. Figure 5 shows the simple graph representation.

$$G = V \cup E \quad (1)$$

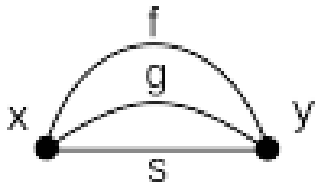

Fig 5: simple graph representation

Normal form of the graph is represented as,

$$f = xy,\ g = xy,\ s = xy \quad (2)$$

Gradient image is used for layer detection. Gradient is the derivative of the image and it contains edge maps of the layers. Difference of the intensity levels with a minimum threshold represents the graph. In the initial stage, it is assumed that the image contains only one layer. A sparse matrix is generated to accommodate all the possible interconnections. The neighborhood pixels are clubbed to make a gradient matrix and these gradient matrices are again compares with adjacent pixel values. Multiple graphs are generated using the linear index of subscriptions. These graphs may have missing links or multiple nodes. Graph shortest path algorithm is exploited to obtain the required graphs by eliminating these problems. Breadth first search (BFS) and Dijakstra are the best algorithm for this.

C. Feature Extraction

The thickness profile can be extracted by calculating the absolute difference between layers of a layer detected choroid and ILM. This step also determines the cyst fluid if any accumulated in the sub retinal layers [20]. In addition, texture features are also extracted to form the feature vector. Feature vector contains,

(i) Thickness profile extraction
(ii) Cyst fluid detection
(iii) Segmentation based Fractal Texture Analysis.

All the vectors are geometric based features. The thickness profile is used to estimate some sub features. They are as follows

(i) Max thickness: It is the maximum value of difference in layers. This represents maximum distance between the layers.

F1=max thickness

(ii) Min thickness: It is the minimum value of difference in layers. This represents minimum distance between the layers.

F2= min thickness

(iii) Thickness variation: The difference between max thickness and min thickness. That is the difference between the layers with occurrence of cyst fluid.

F3=F1-F2

(iv) Maximum cyst area: The amount of fluid accumulated within the retinal layers determines the Maximum Cyst area. This fluid is due to the irregular leakages of other anomalies.

F4= area

(V) Texture Pattern: Segmentation based Fractal Texture Analysis commonly known as SFTA method derives texture patterns arising out of ROI. SFTA is an enhanced version of Two-Threshold Binary Decomposition (TTBD). In this, OTSU method is used to estimate the threshold value [11]. Then the image is decomposed in to binary images I(x, y). The pairs of lower and upper threshold values (tL, tU) are chosen from a group of threshold values, T and the gray-scale ROI is decomposed as,

$$I(x,y) = \begin{cases} 1 & \text{, if } tL < ROI\ (X,Y) < tU \\ 0 & \end{cases} \quad (3)$$

The total number of output images is 2n. The fractal dimension (D) is the main texture feature in this analysis. This estimates the level of irregularities of an image. Different sub features are calculated with this, Average grey level and area of ROI is the sub features that are computed. The border image has the value one and has at least one neighboring pixel value zero. Various approaches are there; among them box counting is one of the most common methods. It is similar to perimeter measuring method. Fractal dimension (D) defined as,

$$D = \frac{\log(N)}{\log(r)} \quad (4)$$

The number of boxes that cover the pattern is represented as N and r is the reciprocal of box size. The feature vectors for every ROI can be pulled out using the feature extraction algorithm.

D. Classification

An efficient and simple classifier need to be used for the accurate classification of the extracted features once the four distinct features are extracted from the OCT images. Quadratic Discriminant Analyzer abbreviated as QDA classify the feature vectors. Consider there are two groups present, y ε {0,1}. The means of each class is defined as $\mu_{y=0}, \mu_{y=1}$. The covariance is given by $\sum_{y=0}, \sum_{y=1}$. using the above, likelihood ratio can be expressed as,

$$\textbf{Ratio}=\left(\frac{\sqrt{2\pi}\,|\sum_{y=1}|^{-1}\exp\left(-\frac{1}{2}(x-\mu_{y=1})^{T}(\sum_{y=1})^{-1}(x-\mu_{y=1}\right.}{\sqrt{2\pi}\,|\sum_{y=0}|^{-1}\exp\left(-\frac{1}{2}(x-\mu_{y=0})^{T}(\sum_{y=1})^{-1}(x-\mu_{y=0}\right.}\right)) < t \quad (5)$$

Where t defines the threshold value. The surface which separates the classes is quadratic in nature. The sample estimates of variance, covariance and the mean vector form the population quantities in the formulae. The covariance is plotted in figure 6

$\sum_k$ Is the covariance matrix

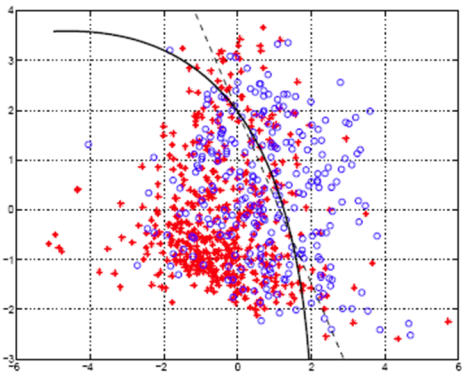

Fig 6: Covariance Matrix

III RESULTS AND DISCUSSION

The database collected from the Heidelberg Engineering Inc.[20]. The dataset contains the OCT scan results from 45 patients. This includes 15 healthy results, 15 patients suffering from AMD and another 15 affected with DME. From this 100 normal and 100 macular edema affected images are taken for the detection and classification. The final results are shown in figure7 and 8 respectively.

A. Macular Edema Image

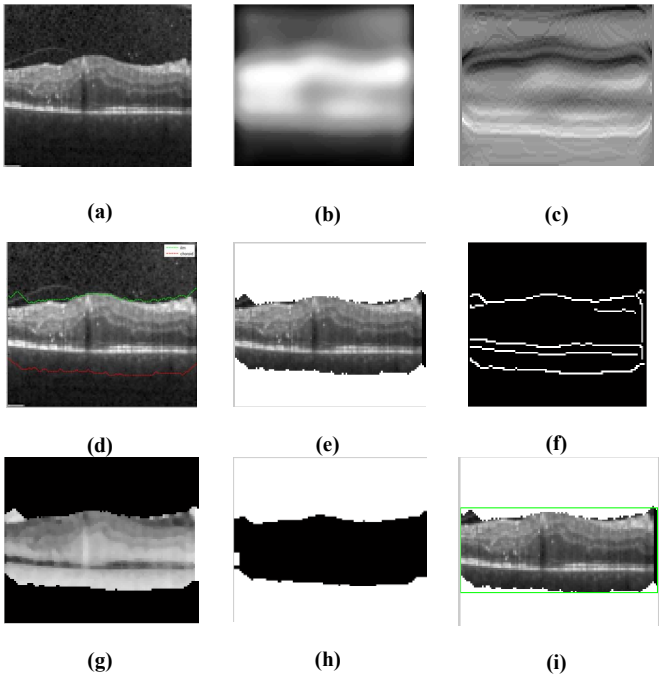

Fig 7: Analysis of Macular Edema (a) Original Image (b) Gaussian filter (c) gradient (d) Layer Detection (e) Segmented image (f) boundary detection (g) median filtered (h) mask (i) Texture

B. Normal Images

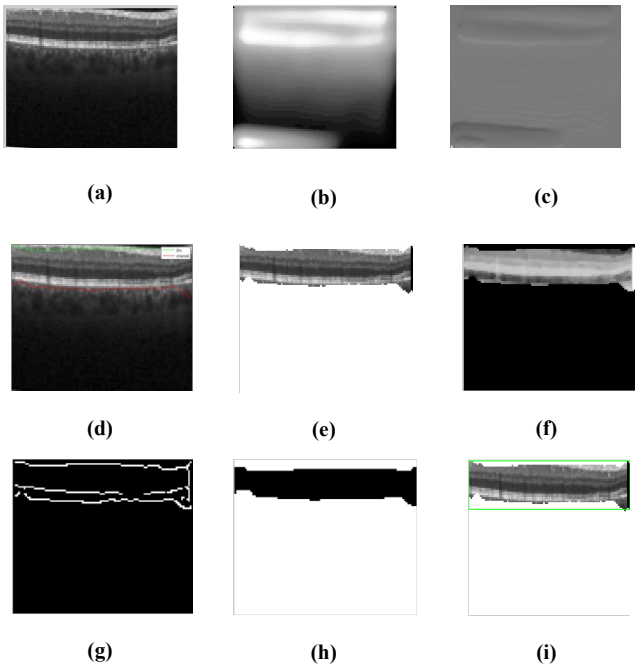

Fig 8: Analysis of Normal Image (a) Input Image (b) Gaussian filter (c) gradient (d) Layer Detection (e) Segmented image (f) boundary detection (g) median filtered (h) mask (i) Texture

TABLE 1: CONFUSION MATRIX

Types	TP	TN	FP	FN
Normal	95	100	2	3
Macular Edema	94	100	5	1

$$\text{Accuracy} = \frac{TP+TN}{TP+TN+FP+FN} = 97.5\%$$

$$\text{Sensitivity} = \frac{TP}{TP+FN} = 98.9\%$$

$$\text{Specificity} = \frac{TN}{FP+TN} = 98.05\%$$

TABLE 2: COMPARISON CHART

Methods	Accuracy	Sensitivity	Specificity
[17]	-	91%	96%
[18]	95.5%	100%	93.75%
Proposed method	97.5%	98.9%	98.05%

VI CONCLUSION AND FUTURE SCOPE

Modern medical technology is the only scope to fight against the ever increasing eye related diseases. ME is one of the major diseases that degrades vision. This paper basically emphasizes on developing a computerized method to detect and diagnose ME at its earlier stages. It utilizes graph based segmentation, SFTA, and QDA algorithms for the detection and classification of ME. The database has been collected from the Heidelberg Engineering Inc. From this 100 normal and 100 macular edema images are taken for the detection and classification. With the proposed, the ophthalmologist can easily identify, the ME and treat the patients at its earlier stages with great level of accuracy that is 97.5%. In future the same algorithm or methodology can be redeployed to identify all eye related anomalies in a single stretch.

REFERENCES

[1] S. C. Athira, Reena M. Roy, "Computerized macular edema detection using OCT images: A review", *Circuits and Systems (ICCS) 2017 IEEE International Conference on*, pp. 404-407, 2017.

[2] Massich, Joan, et al. "Classifying DME vs normal SD-OCT volumes: A review." *Pattern Recognition (ICPR), 2016 23rd International Conference on*. IEEE, 2016.

[3] Ciulla, Thomas A., Armando G. Amador, and Bernard Zinman. "Diabetic retinopathy and diabetic macular edema." *Diabetes care* 26.9 (2003): 2653-2664.

[4] Deepak, K. Sai, and Jayanthi Sivaswamy. "Automatic assessment of macular edema from color retinal images." *IEEE Transactions on medical imaging* 31.3 (2012): 766-776.

[5] Faust, Oliver, et al. "Algorithms for the automated detection of diabetic retinopathy using digital fundus images: a review." *Journal of medical systems* 36.1 (2012): 145-157.

[6] Hassan, Taimur, et al. "Review of OCT and fundus images for detection of Macular Edema." *Imaging Systems and Techniques (IST), 2015 IEEE International Conference on*. IEEE, 2015.

[7] Novosel, Jelena, et al. "Joint Segmentation of Retinal Layers and Focal Lesions in 3-D OCT Data of Topologically Disrupted Retinas." *IEEE Transactions on Medical Imaging* 36.6 (2017): 1276-1286.

[8] Strøm, Charlotte, et al. "Diabetic macular edema assessed with optical coherence tomography and stereo fundus photography." *Investigative ophthalmology & visual science*43.1 (2002): 241-245.

[9] Gilbert, Clare E., et al. "Poverty and blindness in Pakistan: results from the Pakistan national blindness and visual impairment survey." *Bmj* 336.7634 (2008): 29-32.

[10] Sinthanayothin, Chanjira, et al. "Automated detection of diabetic retinopathy on digital fundus images." *Diabetic medicine* 19.2 (2002): 105-112.

[11] Kunwar, Aditya, Shrey Magotra, and M. Partha Sarathi. "Detection of high-risk macular edema using texture features and classification using SVM classifier." *Advances in Computing, Communications and Informatics (ICACCI), 2015 International Conference on*. IEEE, 2015.

[12] Gayathri.R.Nayar 'Partial Palm Multibiostatistics For Personal Authentication'- IJIIE -International Journal Of Innovations & Implementations In Engineering, 2015 April Edition Volume 1.

[13] J A Akhila, Christin Markose, R P Aneesh. "Feature extraction and classification of Dementia with neural network", 2017 nternational Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT), 2017.

[14] Aparna Ratheesh ; Pooja Soman ; M Revathy Nair ; R G Devika ; R P Aneesh "Advanced algorithm for polyp detection using depth segmentation in colon endoscopy" 2016 International Conference on Communication Systems and Networks (ComNet)

[15] T. R. Gayathri, R. P. Aneesh, Gayathri R. Nayar. "Feature based simultaneous localisation and mapping", 2017 IEEE International Conference on Circuits and Systems (ICCS), 2017

[16] Anusree D, K P Sreni, Sangeetha K V, Shilpa M, Vismaya P V 'A Novel Algorithm For Shadow Detection And Reconstruction In High-Resolution Satellite Images'- IJIIE-International Journal Of Innovations & Implementations In Engineering (ISSN 2454-3489) 2016 January Edition Volume 1.

[17] G. R. Wilkins, O. M. Houghton, and A. L. Oldenburg, "Automated segmentation of intraretinal cystoid fluid in optical coherence tomography,"IEEE Trans. Biomed. Eng. 59, 1109–1114 (2012).

[18] P. P. Srinivasan, L. A. Kim, P. S. Mettu, S. W. Cousins, G. M. Comer,J. A. Izatt, and S. Farsiu, "Fully automated detection of diabetic macular edema and dry age-related macular degeneration from optical coherence tomography images," Biomed. Opt. Express 5, 3568

[19] Deepak, K. Sai, and Jayanthi Sivaswamy. "Automatic assessment of macular edema from color retinal images." *IEEE Transactions on medical imaging* 31.3 (2012): 766-776.

[20] Bilal Hassan, et al. "Structure tensor based automated detection of macular edema and central serous retinopathy using optical coherence tomography images", Journal of the Optical Society of America A, 2016